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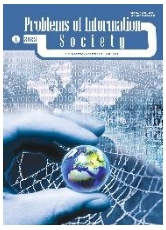

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Ecological assessment of the impact of regional hydrological regime on forest vegetation cover using GIS technologies (on the example of Lachin, Gubadli, and Zangilan regions)

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ABSTRACT

Forests are one of the most important components of the biosphere and represent a resource of immense ecological, economic, cultural, scientific, and recreational value. The social and economic functions of forests are diverse. They play a critical role in soil protection, water and climate regulation, and also serve recreational purposes. As an open ecosystem, forests continuously interact with environmental factors that can influence their condition. Therefore, monitoring the state of forests is essential. For this reason, the study focuses on assessing the condition of forest vegetation. For this purpose, the study focuses on the territories of Lachin, Gubadli, and Zangilan districts, using satellite images from 2000 and 2021. The ENVI and ArcGIS programs are utilized to conduct a quantitative assessment. The NDVI (Normalized Difference Vegetation Index) is employed to analyze forest and vegetation cover, while the MNDWI (Modified Normalized Difference Water Index) is used to assess hydrological conditions. The study primarily investigates the changes in forest and vegetation cover, as well as hydrological status. As a result of the analysis, areas are classified into dry, wet, and water bodies. Changes in dry and wet areas, including increases and decreases in these categories, are identified. Additionally, changes in the state of forest and vegetation cover in these regions are examined. The findings are quantitatively evaluated, and corresponding histograms are constructed to visualize the results.

1. Introduction

Illegal use of forests is one of the most pressing global environmental issues. Illegal logging and the trade of timber are major concerns in countries at various stages of development. Illegal exploitation primarily damages forests with protective functions. Often, impoverished residents of villages lacking access to gas supply are engaged in illegal wood harvesting. The destruction of rare tree and shrub species, whose cutting is prohibited, along with the loss of forest biodiversity during illegal logging, leads to the extinction of numerous species. Such logging, which disregards ecological requirements in forestry, results in the impoverishment of plant species diversity, disruption of ecosystem relationships, and hinders the forest's natural recovery processes.

Currently, geographic information system (GIS) technologies are actively applied in forestry, particularly in forest management, systematic updates in forest fund databases, forest inventory, monitoring organization, and control over forest exploitation. GIS technologies offer numerous advantages and are widely used to address forestry challenges (Application of remote sensing) by leveraging taxonomic forest data, it is possible to create a powerful and flexible model with significant benefits. GIS enables the integration of geographic and tabular data, vector topology (points, lines, and polygons), and raster data models. It also supports the integration of raster and vector images, digital imagery, standard image formats, thematic map visualization, map and table compilation, surveys, and various types of analysis.

The interaction between regional hydrological regimes and forest-vegetation cover has garnered significant attention from specialists. Among the many factors influencing runoff formation, forest cover stands out due to its surface-level characteristics, which can be assessed remotely using modern satellite imagery. Numerous scientific organizations regularly monitor forest cover, and a substantial part of research is dedicated to the hydrological role of forests (Application of remote sensing). However, despite the apparent simplicity of studying forest properties and characteristics in watersheds, scientists have yet to reach a consensus on the hydrological role of forests.

It is well-established that forest cover influences the redistribution of precipitation and evaporation, thereby affecting river flow. The challenge lies in the fact that these relationships are not constant over time and space and are strongly influenced by other factors unrelated to forests. This has led to the emergence of numerous conflicting theories regarding the impact of forest cover on runoff. As part of this broad issue, conducting investigation aimed at identifying the hydrological consequences of deforestation caused by various reasons (unintentional and intentional fires, logging and etc.) is quite relevant for many countries (Application of remote sensing; Forest Resources, 2024; EarthExplorer, 2025; Gusev, 2021; NDVI Maps in ArcGIS, 2025; Xu, 2006; Abbasov, 2001).

2. Related works

Improving the water-saving capacity of deforested lands is one of the key goals in forest landscape restoration. The inefficiency of traditional tools for assessing the forest water conservation function and the complexity of modeling methods do not allow for an effective assessment of the impact of forest restoration on the regional water-saving capacity of forests. To solve this problem, a hybrid model for assessing forest restoration is proposed (Enxu et al., 2021). Combining the forest restoration evaluation model (equivalent recovery area, ERA), classic forest water storage capacity estimation (total water storage capacity), this study takes advantage of ENVI/IDL, ArcGIS Engine/C#.Net to develop the Forest and Water Assessment Tool (FWAT) for assessing the changes of the regional forest landscape and the associated forest water conservation capacity in various forest restoration scenarios. Proposed approach is successfully applied in the Upper Zagunao watershed. Experiments show that artificial restoration measures have a better effect on the forest water conservation function than natural restoration.

Tree removal is generally viewed as undesirable. But systematic repression of this process can lead to gradual loss of microrelief. Restoring natural undulating microrelief in managed forests can help enhance water retention and mitigate runoff, while reducing drought stress and reinforcing forest productivity and resilience. The studies (Martin et al., 2017; Allen, 2010; Archer et al., 2013) present insights on the impact of uprooting on the microrelief of forest soils and forest hydrology, with a focus on its implications for water retention, tree water supply, and forest health. Further research by the authors is aimed at studying the possible consequences of long-term repression of these processes in intensively managed forests, with implications for forest management.

Recently, one of the manifestations of climate change is the threat of floods and expected changes in the water regime in watersheds. In this regard, the relevance of assessing the impact of forests on the hydrology of watersheds is increasing. The studies (Hlásny, 2013; Bíba, 2009) assess the trade-off between the natural conditions of 61 basic watersheds in Slovakia and the expected water-regulating capacity of forests in these watersheds. To calculate a coefficient for each watershed, indicating the need to regulate its water regime, given by natural conditions, and another coefficient, indicating the value of the water-regulating capacity of forests, given by the structure and distribution of the forest, a multi-criteria decision-making scheme is proposed. According to the obtained results, the present structure and distribution of forests in Slovakia have the potential for moderate regulation of the water regime at the scale of basic watersheds.

The article (Mikhailov et al., 2023; Mammadova, 2023; Samidov, 2024) considers the technologies of remote sensing and their applicability in the field of forest protection. An analysis of existing technologies of remote sensing is conducted, the main advantages and disadvantages of these technologies are highlighted, and the prospects for their use in the forest industry are substantiated. According to the authors, the integrated use of remote sensing technologies of the Earth makes it possible to achieve high results in terms of early detection and elimination of forest fires, monitoring the quality of forest exploitation, and suppression of illegal logging.

The aim of this research is to determine the relationship between forest vegetation cover and hydrological conditions using GIS technologies on the example of Lachin, Gubadli, and Zangilan regions. This article presents the results of hydrological condition assessments in the study area, identifies changes, and evaluates their impact on the state of forest vegetation cover in these regions.

3. Materials and Methods

Forest change is a multifaceted, dynamic and continuous process, often interrelated with other land uses, food production and climate systems. These complex relationships and interdependencies are not yet fully understood (Enxu et al., 2021; Martin et al., 2017; Allen, 2010; Rabenilalana et al., 2010). Geographic information systems (GIS) are now widely used in forestry, as in other areas of scientific research, providing extensive capabilities for processing large volumes of geographic data and allowing the creation of a wide variety of thematic layers of electronic maps.

3.1. Indexes for processing information obtained using GIS technologies

To study the state of forest and vegetation cover and surface water in the Lachin, Gubadli and Zangilan regions, ArcGIS software is initially used, in addition to data from Landsat-5 and Landsat-8 satellite images from 2000 and 2021.

In order to determine the relationship between forest cover and the ecological state of the river basin in the Lachin, Gubadli and Zangilan regions, the hydrological status of the forest and vegetation cover and the study area are determined. The Normalized Difference Vegetation Index (NDVI) is used as the forest and vegetation cover, and the Modified Normalized Difference Water Index (MNDWI) are used as the hydrological status.

3.2. Problem solution

To determine the relationship between forest cover and the ecological state of the river basin in the study area, the forest-vegetation cover and hydrological status are assessed. The Normalized Difference Vegetation Index (NDVI) is used as the forest cover index, and the Modified Normalized Difference Water Index (MNDWI) is employed to evaluate the hydrological state (Xu, 2006).

The study utilizes the following corrected images from the Landsat-5 and Landsat-8 satellites (EarthExplorer, 2025; Gusev, 2021).

1. LT05_L1TP_168032_20000604_20200907_02_T1;
2. LT05_L1TP_168033_20000604_20200907_02_T1;
3. LC08_L1TP_169032_20210621_20210629_02_T1;
4. LC08_L1TP_168033_20210630_20210708_02_T1.

NDVI is a simple quantitative indicator of active photosynthetic biomass, often referred to as the vegetation index. It is one of the most widely used indices for the quantitative assessment and analysis of vegetation cover (How to Create NDVI Maps in ArcGIS, 2025) NDVI is calculated using the following formula:

NDVI=NIR−REDNIR+REDNDVI=NIR+REDNIR−RED, where:

- NIR – reflectance in the near-infrared spectrum (μm);
- RED – reflectance in the red spectrum (μm);

According to this formula, the density of vegetation cover (NDVI) at a specific point in the image is determined as the ratio of the difference between the intensities of reflected light in the red and near-infrared ranges to the sum of their intensities.

Based on the results obtained, a classification is performed, and the findings are presented in fig. 1.

On the other hand, the Modified Normalized Difference Water Index (MNDWI) is employed. This index is more effective than the traditional Normalized Difference Water Index (NDWI) for distinguishing water bodies in areas with significant human infrastructure.

The MNDWI minimizes the spectral influence of built-up features (e.g., construction areas), whereas other indices often struggle to differentiate between open water surfaces and artificial structures. For calculation, the visible green (Green) and shortwave infrared (SWIR2) spectral bands are utilized.

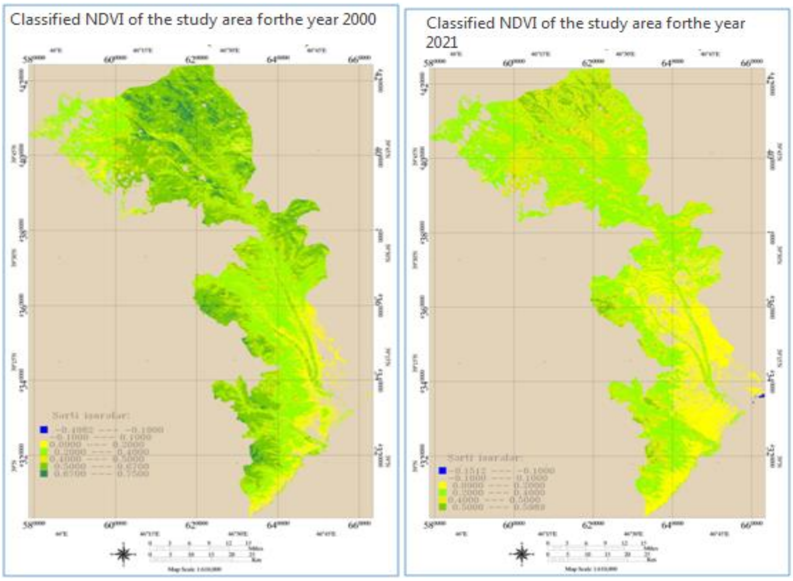


Fig. 1. NDVI index of the study area in 2000 and 2021 by class

The algorithm reduces or eliminates noise effects caused by terrain, soil, and vegetation cover. In regions with dense construction, the MNDWI is preferred over NDWI because it replaces the near-infrared (NIR) band (used in NDWI's formula) with the visible green band, enabling higher accuracy in separating water bodies from built-up areas. The MNDWI ranges between -1 and 1, where water bodies yield positive values (>0) (Xu, 2006).

The MNDWI is calculated using the following formula:

$$MNDWI = \frac{GREEN - SWIR2}{\mathrm{GREEN} + \mathrm{SWIR2}}$$

where:

- Green: Pixel values in the visible green band (Band 2 for Landsat-5 and Band 3 for Landsat-8).
- SWIR2: Pixel values in the shortwave infrared band (Band 7 for both Landsat-5 and Landsat-8).

The MNDWI values are classified into the following ranges:

- -1 to 0: Waterless (dry) areas;
- 0 to 0.3: Waterlogged (wet) soil;
- 0.3 to 1: Water bodies.

A classification is performed, and the results for these three classes are illustrated in fig. 2.

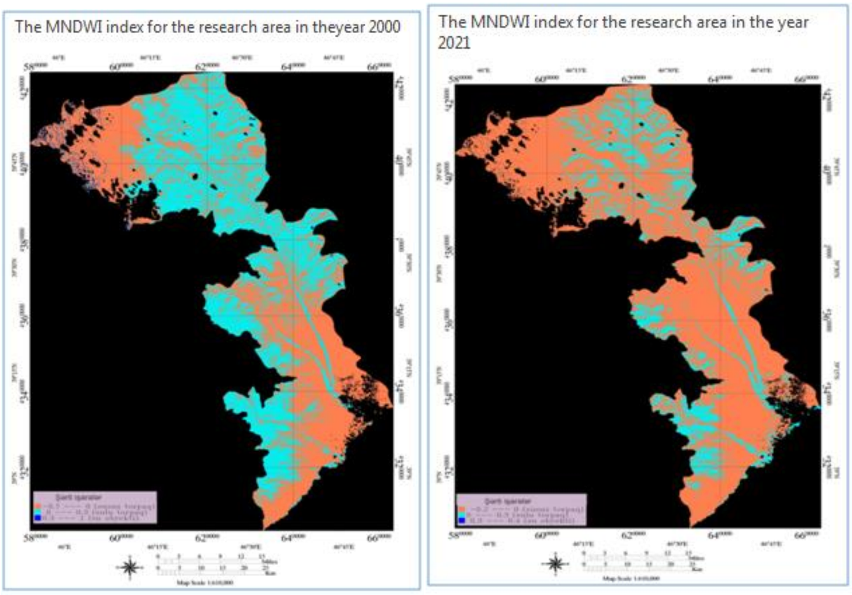


Fig. 2. MNDWI index classified images of the research area for 2000 and 2021

Based on the analyzed satellite imagery, a notable reduction in water body area occurred by 2021. The study area is classified into three categories: waterless (dry) areas, waterlogged (wet) soil, and water bodies. To assess changes in forest and vegetation cover, the analysis focused on tracking expansions and reductions in waterlogged and waterless (dry) zones through comparative evaluation.

The relationship between forest/vegetation cover dynamics and fluctuations in waterless areas is illustrated in fig. 3 and 4, while quantitative area changes are detailed in fig. 5.

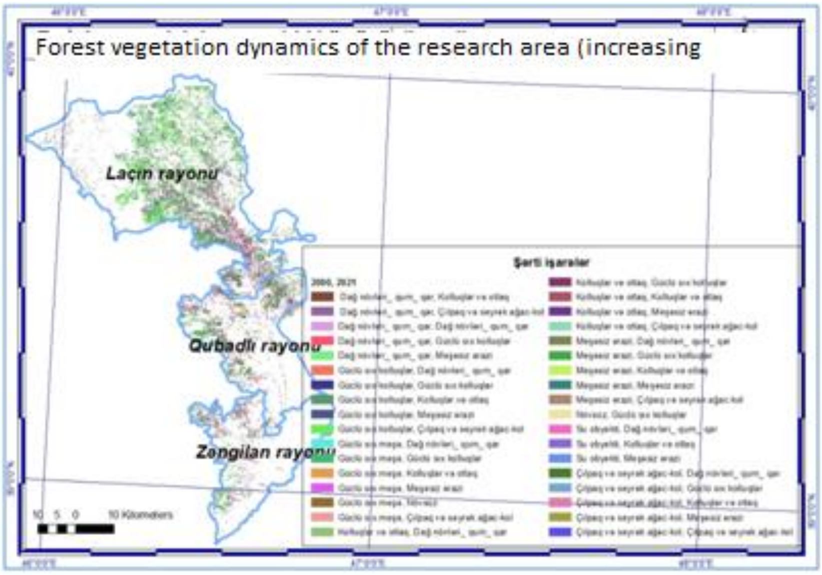


Fig.3. Map of forest-vegetation dynamics of the research area (when dry areas increase)

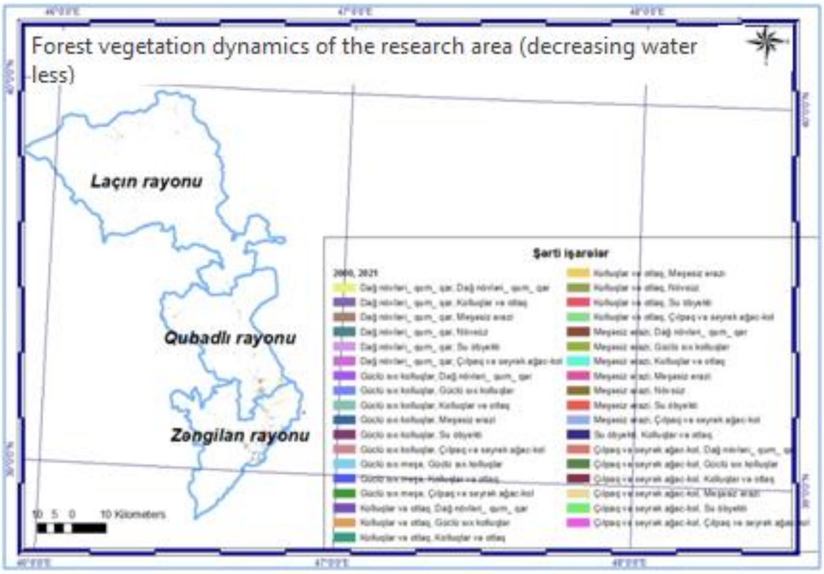


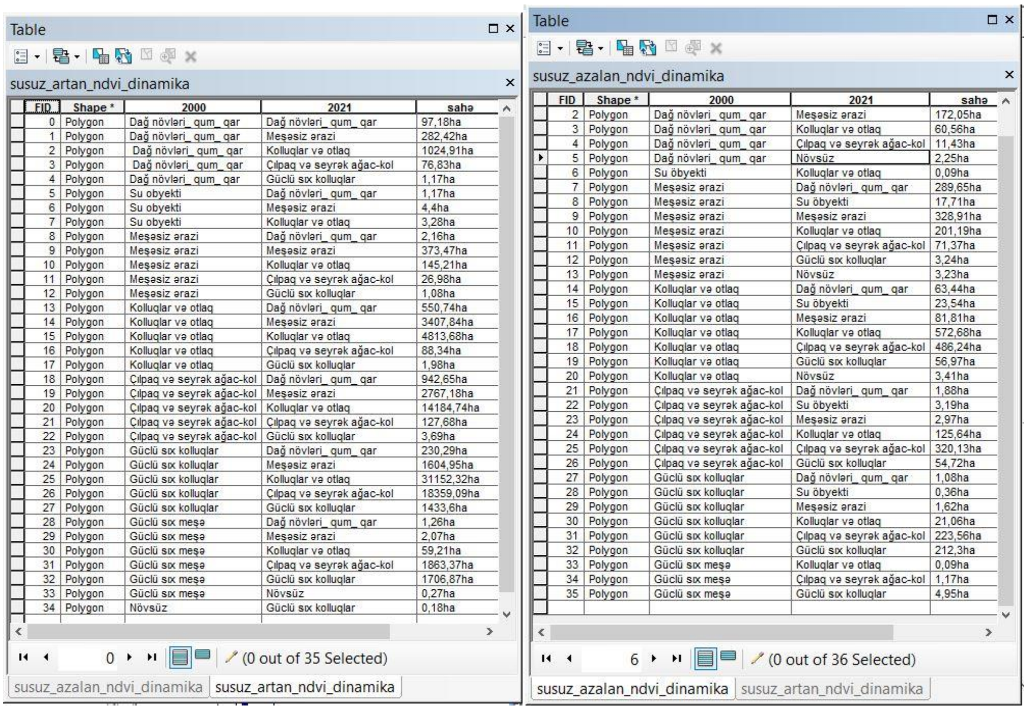
Fig.4. Map of forest-vegetation dynamics of the research area (when dry areas decrease)

The study analyzes the changes in arid land areas and their impact on forest vegetation cover. fig. 4 illustrates the field indicators of forest vegetation cover status in 2000 and 2021, highlighting trends during the expansion and contraction of arid lands. It also details the replacement of one vegetation cover type with another between these years.

3.3. Results of the study

Fig. 3, fig. 4 and table 1 further clarify these dynamics: during periods of arid land expansion, dense vegetation (primarily bushes) dominated the landscape, with concurrent increases in scrubland and pasture areas.

Table 1. Quantitative assessment of the map of forest-vegetation dynamics of the research area (when dry areas increase and decrease)



susuz_artan_ndvi_dinamika

FID	Shape *	2000	2021	sahə
0	Polygon	Dağ növləri_ qum_ qar	Dağ növləri_ qum_ qar	97,18ha
1	Polygon	Dağ növləri_ qum_ qar	Meşəsiz ərazi	282,42ha
2	Polygon	Dağ növləri_ qum_ qar	Kolluqlar və otlaq	1024,91ha
3	Polygon	Dağ növləri_ qum_ qar	Çılpaq və seyrək ağac-kol	76,83ha
4	Polygon	Dağ növləri_ qum_ qar	Güclü sıx kolluqlar	1,17ha
5	Polygon	Su obyekti	Dağ növləri_ qum_ qar	1,17ha
6	Polygon	Su obyekti	Meşəsiz ərazi	4,4ha
7	Polygon	Su obyekti	Kolluqlar və otlaq	3,28ha
8	Polygon	Meşəsiz ərazi	Dağ növləri_ qum_ qar	2,16ha
9	Polygon	Meşəsiz ərazi	Meşəsiz ərazi	373,47ha
10	Polygon	Meşəsiz ərazi	Kolluqlar və otlaq	145,21ha
11	Polygon	Meşəsiz ərazi	Çılpaq və seyrək ağac-kol	26,98ha
12	Polygon	Meşəsiz ərazi	Güclü sıx kolluqlar	1,08ha
13	Polygon	Kolluqlar və otlaq	Dağ növləri_ qum_ qar	550,74ha
14	Polygon	Kolluqlar və otlaq	Meşəsiz ərazi	3407,84ha
15	Polygon	Kolluqlar və otlaq	Kolluqlar və otlaq	4813,68ha
16	Polygon	Kolluqlar və otlaq	Çılpaq və seyrək ağac-kol	88,34ha
17	Polygon	Kolluqlar və otlaq	Güclü sıx kolluqlar	1,98ha
18	Polygon	Çılpaq və seyrək ağac-kol	Dağ növləri_ qum_ qar	942,65ha
19	Polygon	Çılpaq və seyrək ağac-kol	Meşəsiz ərazi	2767,18ha
20	Polygon	Çılpaq və seyrək ağac-kol	Kolluqlar və otlaq	14184,74ha
21	Polygon	Çılpaq və seyrək ağac-kol	Çılpaq və seyrək ağac-kol	127,68ha
22	Polygon	Çılpaq və seyrək ağac-kol	Güclü sıx kolluqlar	3,69ha
23	Polygon	Güclü sıx kolluqlar	Dağ növləri_ qum_ qar	230,29ha
24	Polygon	Güclü sıx kolluqlar	Meşəsiz ərazi	1604,95ha
25	Polygon	Güclü sıx kolluqlar	Kolluqlar və otlaq	31152,32ha
26	Polygon	Güclü sıx kolluqlar	Çılpaq və seyrək ağac-kol	18359,09ha
27	Polygon	Güclü sıx kolluqlar	Güclü sıx kolluqlar	1433,6ha
28	Polygon	Güclü sıx meşə	Dağ növləri_ qum_ qar	1,26ha
29	Polygon	Güclü sıx meşə	Meşəsiz ərazi	2,07ha
30	Polygon	Güclü sıx meşə	Kolluqlar və otlaq	59,21ha
31	Polygon	Güclü sıx meşə	Çılpaq və seyrək ağac-kol	1863,37ha
32	Polygon	Güclü sıx meşə	Güclü sıx kolluqlar	1706,87ha
33	Polygon	Güclü sıx meşə	Növsüz	0,27ha
34	Polygon	Növsüz	Güclü sıx kolluqlar	0,18ha

0 (0 out of 35 Selected)

susuz_azalan_ndvi_dinamika

FID	Shape *	2000	2021	sahə
2	Polygon	Dağ növləri_ qum_ qar	Meşəsiz ərazi	172,05ha
3	Polygon	Dağ növləri_ qum_ qar	Kolluqlar və otlaq	60,56ha
4	Polygon	Dağ növləri_ qum_ qar	Çılpaq və seyrək ağac-kol	11,43ha
5	Polygon	Dağ növləri_ qum_ qar	Növsüz	2,25ha
6	Polygon	Su öbyekti	Kolluqlar və otlaq	0,09ha
7	Polygon	Meşəsiz ərazi	Dağ növləri_ qum_ qar	289,65ha
8	Polygon	Meşəsiz ərazi	Su öbyekti	17,71ha
9	Polygon	Meşəsiz ərazi	Meşəsiz ərazi	328,91ha
10	Polygon	Meşəsiz ərazi	Kolluqlar və otlaq	201,19ha
11	Polygon	Meşəsiz ərazi	Çılpaq və seyrək ağac-kol	71,37ha
12	Polygon	Meşəsiz ərazi	Güclü sıx kolluqlar	3,24ha
13	Polygon	Meşəsiz ərazi	Növsüz	3,23ha
14	Polygon	Kolluqlar və otlaq	Dağ növləri_ qum_ qar	63,44ha
15	Polygon	Kolluqlar və otlaq	Su öbyekti	23,54ha
16	Polygon	Kolluqlar və otlaq	Meşəsiz ərazi	81,81ha
17	Polygon	Kolluqlar və otlaq	Kolluqlar və otlaq	572,68ha
18	Polygon	Kolluqlar və otlaq	Çılpaq və seyrək ağac-kol	486,24ha
19	Polygon	Kolluqlar və otlaq	Güclü sıx kolluqlar	56,97ha
20	Polygon	Kolluqlar və otlaq	Növsüz	3,41ha
21	Polygon	Çılpaq və seyrək ağac-kol	Dağ növləri_ qum_ qar	1,88ha
22	Polygon	Çılpaq və seyrək ağac-kol	Su öbyekti	3,19ha
23	Polygon	Çılpaq və seyrək ağac-kol	Meşəsiz ərazi	2,97ha
24	Polygon	Çılpaq və seyrək ağac-kol	Kolluqlar və otlaq	125,64ha
25	Polygon	Çılpaq və seyrək ağac-kol	Çılpaq və seyrək ağac-kol	320,13ha
26	Polygon	Çılpaq və seyrək ağac-kol	Güclü sıx kolluqlar	54,72ha
27	Polygon	Güclü sıx kolluqlar	Dağ növləri_ qum_ qar	1,08ha
28	Polygon	Güclü sıx kolluqlar	Su öbyekti	0,36ha
29	Polygon	Güclü sıx kolluqlar	Meşəsiz ərazi	1,62ha
30	Polygon	Güclü sıx kolluqlar	Kolluqlar və otlaq	21,06ha
31	Polygon	Güclü sıx kolluqlar	Çılpaq və seyrək ağac-kol	223,56ha
32	Polygon	Güclü sıx kolluqlar	Güclü sıx kolluqlar	212,3ha
33	Polygon	Güclü sıx meşə	Kolluqlar və otlaq	0,09ha
34	Polygon	Güclü sıx meşə	Çılpaq və seyrək ağac-kol	1,17ha
35	Polygon	Güclü sıx meşə	Güclü sıx kolluqlar	4,95ha

6 (0 out of 36 Selected)

Conversely, during arid land contraction, scrubland and pasture coverage remained the Largest component, while non-forested areas declined. Notably, bare land and areas with sparse trees/shrubs expanded during this phase.

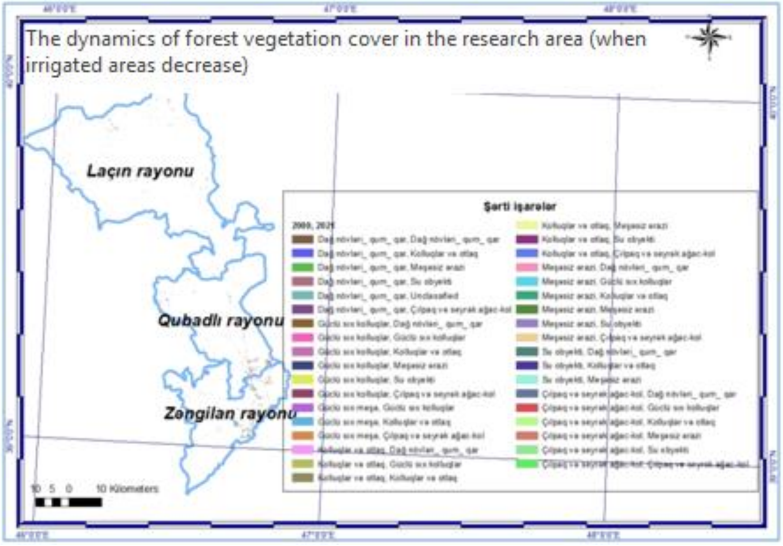


Fig.5. Map of forest-vegetation dynamics of the research area (when wetlands increase)

The analysis then focuses on arid land areas (both increasing and decreasing zones). Fig. 5 and fig. 6 depict the shifts in forest vegetation cover resulting from these arid land changes, while table 2 provides supporting field-based indicators (e.g., soil moisture, species composition) to contextualize.

According to fig. 5, fig. 6 and table 2 the dynamics of vegetation cover correlate strongly with changes in irrigated land area: Increased irrigated land area led to a decline in shrubs and pastures and a sharp rise in bare land and sparse trees/shrubs. Conversely, decreased irrigated land area resulted in a significant expansion of shrubs and pastures alongside a marked decline in dense vegetation (shrubs).

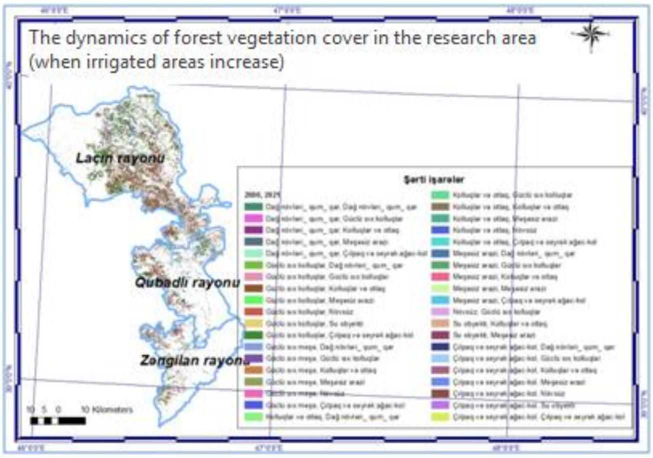
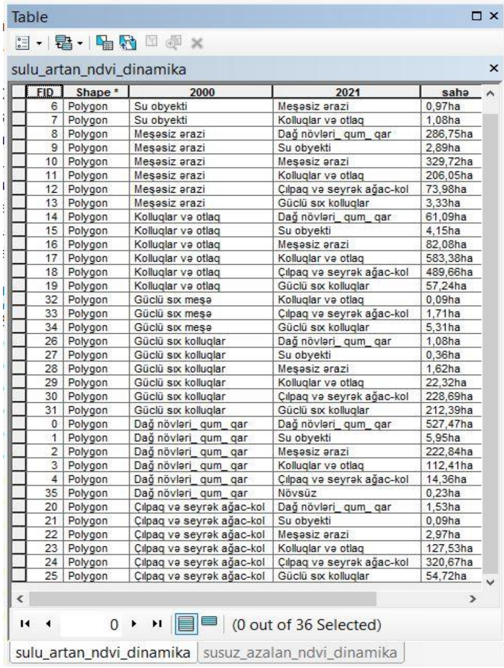


Fig. 6. Map of forest-vegetation dynamics
of the research area (when wetlands are decreasing)

Table 2. Quantitative assessment of the map of forest-vegetation dynamics
of the research area (when wetlands increase and decrease)



FID	Shape *	2000	2021	sahə
6	Polygon	Su obyekti	Meşəsiz ərazi	0,97ha
7	Polygon	Su obyekti	Kolluqlar və otlaq	1,08ha
8	Polygon	Meşəsiz ərazi	Dağ növləri_ qum_ qar	286,75ha
9	Polygon	Meşəsiz ərazi	Su obyekti	2,89ha
10	Polygon	Meşəsiz ərazi	Meşəsiz ərazi	329,72ha
11	Polygon	Meşəsiz ərazi	Kolluqlar və otlaq	206,05ha
12	Polygon	Meşəsiz ərazi	Çılpaq və seyrək ağac-kol	73,98ha
13	Polygon	Meşəsiz ərazi	Güclü sıx kolluqlar	3,33ha
14	Polygon	Kolluqlar və otlaq	Dağ növləri_ qum_ qar	61,09ha
15	Polygon	Kolluqlar və otlaq	Su obyekti	4,15ha
16	Polygon	Kolluqlar və otlaq	Meşəsiz ərazi	82,08ha
17	Polygon	Kolluqlar və otlaq	Kolluqlar və otlaq	583,38ha
18	Polygon	Kolluqlar və otlaq	Çılpaq və seyrək ağac-kol	489,66ha
19	Polygon	Kolluqlar və otlaq	Güclü sıx kolluqlar	57,24ha
32	Polygon	Güclü sıx meşə	Kolluqlar və otlaq	0,09ha
33	Polygon	Güclü sıx meşə	Çılpaq və seyrək ağac-kol	1,71ha
34	Polygon	Güclü sıx meşə	Güclü sıx kolluqlar	5,31ha
26	Polygon	Güclü sıx kolluqlar	Dağ növləri_ qum_ qar	1,08ha
27	Polygon	Güclü sıx kolluqlar	Su obyekti	0,36ha
28	Polygon	Güclü sıx kolluqlar	Meşəsiz ərazi	1,62ha
29	Polygon	Güclü sıx kolluqlar	Kolluqlar və otlaq	22,32ha
30	Polygon	Güclü sıx kolluqlar	Çılpaq və seyrək ağac-kol	228,69ha
31	Polygon	Güclü sıx kolluqlar	Güclü sıx kolluqlar	212,39ha
0	Polygon	Dağ növləri_ qum_ qar	Dağ növləri_ qum_ qar	527,47ha
1	Polygon	Dağ növləri_ qum_ qar	Su obyekti	5,95ha
2	Polygon	Dağ növləri_ qum_ qar	Meşəsiz ərazi	222,84ha
3	Polygon	Dağ növləri_ qum_ qar	Kolluqlar və otlaq	112,41ha
4	Polygon	Dağ növləri_ qum_ qar	Çılpaq və seyrək ağac-kol	14,36ha
35	Polygon	Dağ növləri_ qum_ qar	Növsüz	0,23ha
20	Polygon	Çılpaq və seyrək ağac-kol	Dağ növləri_ qum_ qar	1,53ha
21	Polygon	Çılpaq və seyrək ağac-kol	Su obyekti	0,09ha
22	Polygon	Çılpaq və seyrək ağac-kol	Meşəsiz ərazi	2,97ha
23	Polygon	Çılpaq və seyrək ağac-kol	Kolluqlar və otlaq	127,53ha
24	Polygon	Çılpaq və seyrək ağac-kol	Çılpaq və seyrək ağac-kol	320,67ha
25	Polygon	Çılpaq və seyrək ağac-kol	Güclü sıx kolluqlar	54,72ha

0 (0 out of 36 Selected)

FID	Shape *	2000	2021	sahə
0	Polygon	Dağ növləri_ qum_ qar	Dağ növləri_ qum_ qar	66,59ha
1	Polygon	Dağ növləri_ qum_ qar	Meşəsiz ərazi	196,65ha
2	Polygon	Dağ növləri_ qum_ qar	Kolluqlar və otlaq	301,06ha
3	Polygon	Dağ növləri_ qum_ qar	Çılpaq və seyrək ağac-kol	18,34ha
4	Polygon	Dağ növləri_ qum_ qar	Güclü sıx kolluqlar	0,27ha
5	Polygon	Su obyekti	Meşəsiz ərazi	1,26ha
6	Polygon	Su obyekti	Kolluqlar və otlaq	0,54ha
7	Polygon	Meşəsiz ərazi	Dağ növləri_ qum_ qar	2,16ha
8	Polygon	Meşəsiz ərazi	Meşəsiz ərazi	373,29ha
9	Polygon	Meşəsiz ərazi	Kolluqlar və otlaq	136,39ha
10	Polygon	Meşəsiz ərazi	Çılpaq və seyrək ağac-kol	24,1ha
11	Polygon	Meşəsiz ərazi	Güclü sıx kolluqlar	0,9ha
12	Polygon	Kolluqlar və otlaq	Dağ növləri_ qum_ qar	550,38ha
13	Polygon	Kolluqlar və otlaq	Meşəsiz ərazi	3407,66ha
14	Polygon	Kolluqlar və otlaq	Kolluqlar və otlaq	4799,73ha
15	Polygon	Kolluqlar və otlaq	Çılpaq və seyrək ağac-kol	81,32ha
16	Polygon	Kolluqlar və otlaq	Güclü sıx kolluqlar	1,71ha
17	Polygon	Kolluqlar və otlaq	Növsüz	0,26ha
18	Polygon	Çılpaq və seyrək ağac-kol	Dağ növləri_ qum_ qar	942,47ha
19	Polygon	Çılpaq və seyrək ağac-kol	Su obyekti	0,45ha
20	Polygon	Çılpaq və seyrək ağac-kol	Meşəsiz ərazi	2767ha
21	Polygon	Çılpaq və seyrək ağac-kol	Kolluqlar və otlaq	14182,5ha
22	Polygon	Çılpaq və seyrək ağac-kol	Çılpaq və seyrək ağac-kol	127,41ha
23	Polygon	Çılpaq və seyrək ağac-kol	Güclü sıx kolluqlar	3,69ha
24	Polygon	Çılpaq və seyrək ağac-kol	Növsüz	0,27ha
25	Polygon	Güclü sıx kolluqlar	Dağ növləri_ qum_ qar	230,29ha
26	Polygon	Güclü sıx kolluqlar	Su obyekti	0,09ha
27	Polygon	Güclü sıx kolluqlar	Meşəsiz ərazi	1604,59ha
28	Polygon	Güclü sıx kolluqlar	Kolluqlar və otlaq	31149,35ha
29	Polygon	Güclü sıx kolluqlar	Çılpaq və seyrək ağac-kol	18357,56ha
30	Polygon	Güclü sıx kolluqlar	Güclü sıx kolluqlar	1433,51ha
31	Polygon	Güclü sıx kolluqlar	Növsüz	0,58ha
32	Polygon	Güclü sıx meşə	Dağ növləri_ qum_ qar	1,26ha
33	Polygon	Güclü sıx meşə	Meşəsiz ərazi	2,07ha
34	Polygon	Güclü sıx meşə	Kolluqlar və otlaq	59,21ha
35	Polygon	Güclü sıx meşə	Çılpaq və seyrək ağac-kol	1863,01ha
36	Polygon	Güclü sıx meşə	Güclü sıx kolluqlar	1706,6ha
37	Polygon	Güclü sıx meşə	Növsüz	0,27ha
38	Polygon	Növsüz	Güclü sıx kolluqlar	0,18ha

0 (0 out of 39 Selected)

These trends are summarized in table 3 and visualized in the accompanying histogram (fig. 7).

In table 3, the symbols ↑ (increase) and ↓ (decrease) indicate the direction of observed changes.

Table 3. Trends in Irrigated and Waterlogged Land Areas by Land Cover Type

Land Cover Type	Wetland		Non-Wetland	
	Increase	Decrease	Increase	Decrease
Water Body	11,39↑	0,72↓	8,85↓	3,1↑
Mountain, Sand, Snow	5,34↓	1210,24↑	342,94↑	109,76↑
Non-Forested Area	262,52↑	7815,68↑	7894,33↑	327,94↓
Shrubs and Pasture	223,93↓	41787,72↑	42520,77↑	306,78↓
Barren Land and Sparse Trees/Shrubs	621,56↑	2447,95↑	2388,67↑	604,2↑
Dense Vegetation (Shrubs)	190,71↓	32304,2↓	51342,24↓	127,8↓
Dense Vegetation (Forest)	7,11↓	3632,42↓	3633,05↓	6,21↓
Unclassified/Other	0,23↑	1,2↑	0,18↑	8,89↑

As can be seen from the table, the dynamics of the increasing and decreasing areas of irrigated and non-irrigated land is reflected. The largest area occurred in the regions of shrubs and pastures, and additionally, in the areas of dense shrubs.

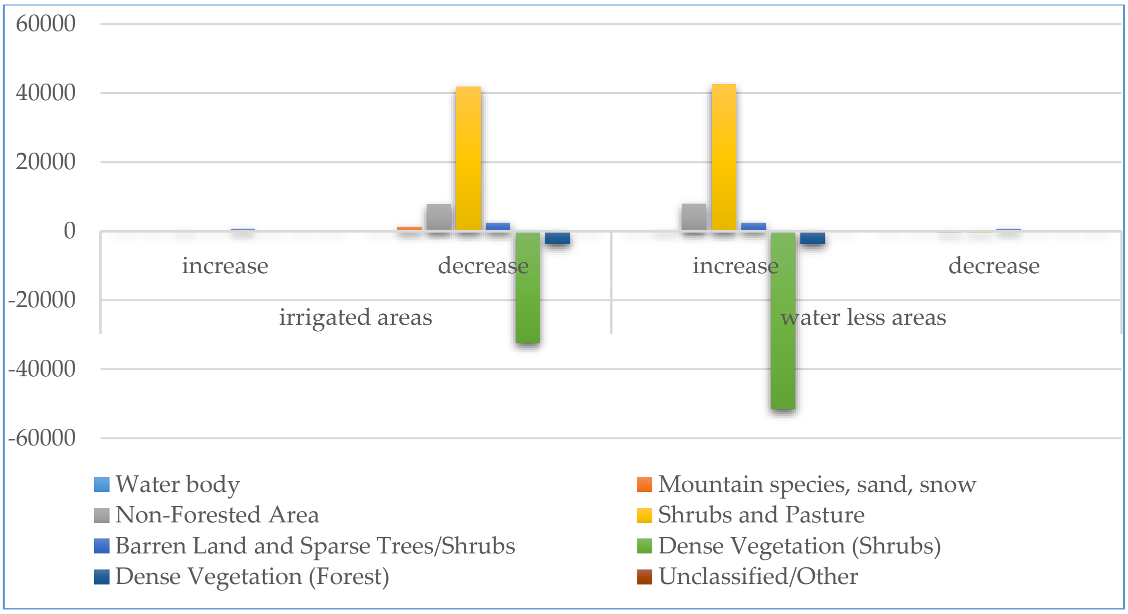


Fig. 7. Histogram of Forest and Vegetation Cover Dynamics in the Study Area

Based on the histogram shown in fig. 9, it can be observed that the main changes occur when the area of irrigated land decreases and the area of non-irrigated land increases. Specifically, when the area of irrigated land decreases, the most significant change is the reduction in the area of dense vegetation and the increase in shrubs and pastures. On the other hand, when the area of non-irrigated land increases, the area of shrubs and pastures expands, while the area of dense vegetation (shrubs) decreases.

4. Discussion

Forests are ecosystems with an exceptionally high capacity to regulate water, albeit at different scales. Therefore, optimizing forest structure and distribution should be considered an important concept in the integrated management of watersheds. It is clear that all the current issues in forestry (such as violations in forest management, protection of old forests, combating illegal logging, restoration of forests, and their water balance) require up-to-date and accurate information about forests and water resources for effective solutions. Currently, such sources of information are limited, and access to this data is restricted.

The application of GIS technologies in forestry enables the creation of a database on forest resources and water bodies, the compilation and updating of a forest register, the monitoring of forest and vegetation cover, and the control of their exploitation. GIS technologies facilitate the collection of accurate and multifaceted information on the hydrological regimes, as well as forest and vegetation cover, of a specific area (in this study, the territories of Lachin, Gubadli, and Zangilan regions) at a given time.

Aerospace methods of studying the indicated areas allow for the creation of a wide range of thematic layers for electronic maps of forest and vegetation cover, monitoring the dynamics of changes in forest and vegetation cover, and assessing the degree of influence of the regional hydrological regime on them (fig.1-9).

Due to financial difficulties in obtaining high-resolution images to conduct the study, the results are likely to be somewhat less accurate. In the future, it is planned to compile maps for other years and provide forecasts.

5. Conclusion

The study yielded the following key findings:

1. Water Bodies: Increased wet land area correlated with expansion of water bodies, while reduced dry land area also contributed to their growth.
2. Mountain, Sand, and Snow Areas: These land cover types expanded most significantly when wet land area decreased and dry land area increased.

3. Non-Forested Areas: Expansion occurred predominantly under conditions of declining wet land area and rising dry land area.
4. Shrubs and Pastures: Increased coverage was linked to reduced wet land area and expanded dry land area.
5. Bare and Sparse Tree/Shrub Areas: Growth in these areas coincided with declines in wet land area and increases in dry land area.
6. Dense Vegetation (Shrubs): Expansion occurred when wet land area decreased and dry land area increased.
7. Dense Vegetation (Forest): Forest cover declined with reduced irrigated land area and expanded arid land area.

Key Insight: The reduction of arid land area was strongly associated with increased coverage of dense vegetation (shrubs and forests). Conversely, expanded arid lands and reduced irrigation correlated with vegetation loss.

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